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ELECTRONIC RECYCLING AND ITS IMPACT ON THE MUNICIPAL MANAGEMENT OF THE CITY OF BABAHOYO

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Abstract

The impact of human activity on the environment has direct repercussions on the well-being of society as a whole. In this context, the management of solid waste is an obligation that under Ecuadorian legislation is the responsibility of the decentralized autonomous governments; however, not all waste is the same, and electronic waste requires special treatment, so the objective of this analysis is to diagnose the management of electronic waste in the city of Babahoyo. To meet the proposed objective, methods such as analytical - synthetic, inductive - deductive, historical - logical, systemic, and techniques and instruments such as the survey and the AHP Saaty multi-criteria decision method were used. The criteria that can contribute to the improvement of the e-waste management process stated in the objective were identified and prioritized to propose actions aimed at improving it.

Keywords: recycling, ordinances, electronic scrap.

Introduction

Currently, there is a worldwide problem that consists of the amount of waste generated by each inhabitant. Among the most dangerous are electronic wastes, because they present difficulties for their recycling. E-waste is treated as common garbage, without taking into account a large number of toxic components it contains and the serious repercussions it has on the environment (Aguilera, 2010). A relevant aspect in the cities of developing countries is the informality in the recovery and recycling of these wastes, which generates potential impacts on the health of the people who are part of the recycling chains, who release toxic elements such as heavy metals and acids contained in parts of the equipment without technical control, also impacting the environment (PINCAY CHIQUITO, 2020)

It is important to consider that there are resources that can be recovered from these wastes, being precious metals one of the materials that, despite not having a large volume, can be exploited productively, since when these materials reach landfills, they release toxic substances that affect the environment (Calderón, 2015). This waste recovery process is known as recycling, and according to (Maldonado, 2006), it is understood as the process that transforms waste or used materials into new goods or products for reuse.

There are international regulations such as the Basel Convention for the management of electronic waste, and in Ecuador in particular, there are only ministerial agreements, Ministerial Agreement No. 191 Instructions for Cell Phone Recycling, which is aimed at encouraging importers to adopt the principle of extended responsibility to reduce environmental impact. The scope of application of the instructions is the management of disused cellular equipment, including its components and constituent elements (Ambiente, 2013b). Finally, the Ministerial Agreement on Instructions for the Management of Used Batteries is aimed at establishing environmental parameters and specifications for the destination of the Integrated Management Plan for Used Batteries, encouraging the reduction and other forms of use of the same to protect the environment. This agreement also indicates that, under its management, the recovery of these batteries should be carried out in such a way as to have the least possible risk and environmental impact (Ambiente, 2013a).

Ministerial Agreement No. 190, on the National Post-consumption Policy for Electrical and Electronic Equipment, has the general objective of establishing norms on the national policy for the post-consumption of disused equipment, based on applicable national legislation and national management capacities, also considering international trends. The National Environmental Authority has the responsibility and obligation to carry out the verification of compliance with the activities linked to the Integrated Management Plan for Used Batteries in its jurisdiction (Ambiente, 2013a), on extended responsibility, the Organic Environmental Code, in Article 217 states that producers have the responsibility for the product cycle, that is, the usefulness of the product until it becomes a waste or waste (Moscoso, 2019).

At the international level, the Basel Convention is considered one of the most important concerning e-waste management. One of its main objectives is to reduce the transfer of hazardous waste from developed to developing countries. To establish the definition of which wastes are considered hazardous, in 1994 the States affiliated with the Basel Convention established two lists of elements corresponding to two different levels of hazardousness “A and B”, electronic equipment is present in both lists, for this international regulation of Hazardous Waste management, the most important is the state and levels of contamination present in electronic waste and the impact they have on health or the environment. (UNEP., 1992).

Around 5.5 kilograms of electronic waste are generated per inhabitant per year, and these remains constitute the largest number of heavy alloys and polluting substances in the environment, causing intoxication in Ecuador. Mobile devices, batteries, batteries, computers, electronic cards, and cameras, among others, are discarded as part of urban solid waste (Alarcón et al., 2019).

To convert this waste into secondary raw materials, a commitment must be made by all the actors that make up the recycling chain, mainly consumers, who must know that the devices have a different treatment than traditional garbage. In practice, some companies are dedicated to the management of electronic waste for obtaining electronic parts, once the waste is obtained, they start with the separation of the pieces containing gold and other minerals (Rojas-Vargas & Bogantes, 2018).

Raw material recovery from technological waste has the potential to make a substantial contribution to the resource needs of the local economy. Resource recovery is already worldwide. However, it varies from country to country depending on many local factors (Sanchez & Moura, 2005). Technological waste, also known as E-waste is one of the categories of potential sources of resources in urban areas because Waste Electrical and Electronic Equipment (WEEE) is increasing at an accelerated rate such that it can exceed the level of plastic packaging waste. However, WEEE is more dangerous and toxic for living beings and the planet in general (Monar Bastidas, 2021).

One of the main causes of this increase in pollution generated by electronic equipment is that technology is constantly being renewed, and devices deteriorate and become useless over time, this causes the generation of large amounts of electronic waste each year. Despite the existence of global figures and a formally established methodology to calculate the generation of electronic and electrical waste, it can be concluded that Latin America will be responsible for the problem that arises due to the final treatment of an increasing amount of technological equipment that is at the end of its useful life, currently considered as a critical mass in Latin America (Silva, 2009).

To achieve an adequate recycling process, the key is to take the waste to places where it will be treated more conveniently. However, this does not prevent the growth of technological waste, which is why several environmental organizations are committed to practices such as reducing technological consumption, i.e., not changing devices until it is really necessary and encouraging them to fix them before buying a new one. Electronic devices that are used daily can have a second chance if a proper recycling process is carried out. Users, the main actors of a process, should offer the possibility of reuse; and, on the other hand, it helps to sustainable and environmentally responsible decontamination. Achieving awareness of the environmental dimension and acting responsibly in this regard is a process that should start from educational institutions, to achieve the sustainability of the processes that occur in society (Minguet et al., 2014).

In 2018, Ecuadorians produced around 93 000 tons of waste electrical and electronic equipment; that is, approximately 5.4 kg per person. Only 2% of this value was recycled. In Ecuador, some companies work and encourage the collection of these devices to reuse their parts (Forti et al., 2020).

One of the methods used to achieve social awareness of the environmental dimension and the importance of recycling and sustainability is communication campaigns, which show an impact on the actions of individuals and a change in the communities (Moreno & Núñez, 2016). In Ecuador, e-waste recycling campaigns have been initiated with the support of private institutions, as part of their social responsibility for the care of the environment, one of these companies is Telefónica Movistar, in a project in conjunction with the Ministry of Environment, which is called “Connect with the planet”. This plan is based on training public officials on the proper management of e-waste.

Companies, computer repair shops, cellular phones, and the Ecuadorian society have the problem of electronic waste accumulated in their warehouses, without having options on how to dispose of it. Within this garbage, there are components such as copper, aluminum, gold, and integrated components that are in good condition. Although the Ministry of the Environment has registered five nationally certified environmental managers to contribute to the recycling and processing of electronic waste, Reciclamental and Vertmonde are two of the main companies, located in the city of Quito, that treat this waste. Virtumonde is the first Ecuadorian company in the country to implement a specialized recycling program for electrical and electronic waste through technical and environmentally responsible processes that are unique in Ecuador. The technical manager of this recycling company indicates that these products are composed of metals, which must have a special treatment, since, if this waste is left in the environment, all its elements such as metals, are spread in the soil and it becomes unfit for planting since the food will be contaminated with them (Ecuador, 2018).

The problem of electronic waste is transversal in several cantons of the country, as explained by López Barrera & Saquisili Villacres (2017), who state that in the city of Milagro, province of Guayas, the management of electronic waste is carried out as if it were a common waste, that is, it is transferred along with other waste to the landfill, where the components of electronic boards are diluted among the organic material contaminating with heavy metals and highly toxic leachates from the process of decomposition of the garbage. At the Universidad Católica Santiago de Guayaquil through a thesis project in 2019, it was proposed the creation of an electronic waste recycling center in the city of Guayaquil named “Electrotrash” to treat waste by chemical methods that allow the separation of metals that exist them such as gold, aiming to be a 100% eco-friendly company (Bermudez, 2019).

Having made a preliminary study in the premises of the city of Babahoyo, 187 premises of establishments that handle electronic waste were found in this category: sale, repair, and spare parts of cell phones, various appliances, computers, and office equipment. These establishments generate a considerable volume of electronic waste, on many occasions, without differentiation in their treatment. In recent years, electronic recycling has been appearing in an isolated and disjointed manner, so it is a priority to start working on a policy in the city of Babahoyo on the treatment of technological waste, which is currently being deposited in landfills, with the risk of contaminating the water sources of the cities. Therefore, the objective of this analysis is to diagnose the management of electronic waste in the city of Babahoyo and the need for an ordinance to regulate it.

METHODS

Analytic - synthetic

It allows the decomposition of the whole in specific aspects to understand and comprehend the structure; it facilitated the observation to better understand the components. In this context, this method implies synthesis, i.e., the union of the dispersed elements to form a total component (Mellado, 1974).

Inductive - deductive

This research method allows for logical reasoning. While the inductive method starts from specific premises to reach general aspects, the deductive method is the opposite, since it starts from the generic to reach particular aspects. However, both methods are essential in the construction of knowledge (Newman, 2006).

Historical – logical

These methods allow the construction of the research from the historical elements that build the research to understand the essential elements of the research and its historical evolution (Rivero, 2017).

Systemic

Through this method, it was possible to group each of the phenomena mentioned in the research as facts isolated from reality and isolated from each other, which, based on a theory, gave rise to the unification of the various elements.

Bibliographic research

Additionally, bibliographic research was used to collect data and structure the thematic content required to understand the problem.

Survey

Using this technique, questions were elaborated to obtain concrete information on the management of electronic waste in the city of Babahoyo.

Proposed questionnaire:

To learn about the management of electronic waste, we need your cooperation through the response to the following questions, whose results are confidential and for scientific purposes, thank you for your help.

1- What type of electronic equipment have you discarded during the year 2021?

2- On average, how many kg of e-waste do you estimate you produce per month?

3- Where do you place the e-waste you produce?

4- Do you know of any local regulations governing e-waste management?

5- Have you been instructed by any entity on e-waste management?

6- Do you think it is necessary to create an ordinance to improve the recycling of the electronic waste in Babahoyo?

Population and sample

Population: the universe of individuals to be considered for the study.

Sample: representative quantity of the population under study to be determined with the Formula (1).

$$n = \frac{N\sigma^2 Z^2}{(N-1)e^2 + \sigma^2 Z^2} \quad (1)$$

Where:

n = sample size.

N = population size.

σ= standard deviation of the population which, generally when its value is not available, a constant value of 0.5 is usually used.

Z = confidence level value, 95%.

e = is the maximum margin of error allowed, which is 5%.

AHP Saaty Method

The Analytic Hierarchical Process (AHP Saaty) was proposed by Thomas Saaty in 1980 (Saaty, 2014). It is one of the most widespread methods for solving multi-criteria decision-making problems. This technique models the problem leading to the formation of a hierarchy representative of the associated decision-making scheme. This hierarchy presents at the top level the objective to be pursued in the solution of the problem and at the lower level the different alternatives from which a decision must be made. The intermediate levels detail the set of criteria and attribute considered.

In the late 1970s, Professor Saaty (1980), a doctor of mathematics at Yale University, created a mathematical model called the Analytical Hierarchy Process (AHP) as an effective way to define measures for such elements and use them in decision-making processes. AHP is a theory oriented towards the decision-maker and serves to identify the best alternative according to the resources allocated. This method can be applied to situations involving technical, economic, political, social, and cultural factors. In other words, it is intended as a scientific tool to address those aspects that are difficult to quantify, but sometimes require a unit of measurement (Saaty, 2014).

Some authors argue that the AHP has not been well understood, since it goes beyond being a simple methodology for choice situations. It is posited then, that the best way to understand the method is by describing its three basic functions: structuring complexity, measuring on a scale, and synthesizing. These are described briefly below.

Structuring Complexity. Saaty sought a way to solve the complexity problem, and used hierarchical structuring of problems into homogeneous sub-problems.

Measurement in scales. The AHP allows measurements of both subjective and objective factors from numerical, verbal, or graphical estimates, which provides great flexibility, allowing a wide variety of applications in fields as different from each other.

Synthesis. Although the name includes the word Analysis, the AHP approach is systemic since, although it analyzes the decisions from the hierarchical decomposition, it never loses sight of the general objective and the interdependencies existing between the sets of factors, criteria, and alternatives, therefore, this method is focused on the system in general, and the solution it presents is for the totality, not for the particularity.

The process is based on several stages. The formulation of the decision-making problem in a hierarchical structure is the first and main stage. This stage is where the decision maker must break down the problem into its relevant components. The basic hierarchy is composed of general goals or objectives, criteria, and alternatives; the hierarchy is constructed in such a way that the elements are of the same order of magnitude and can be related to some of the next levels.

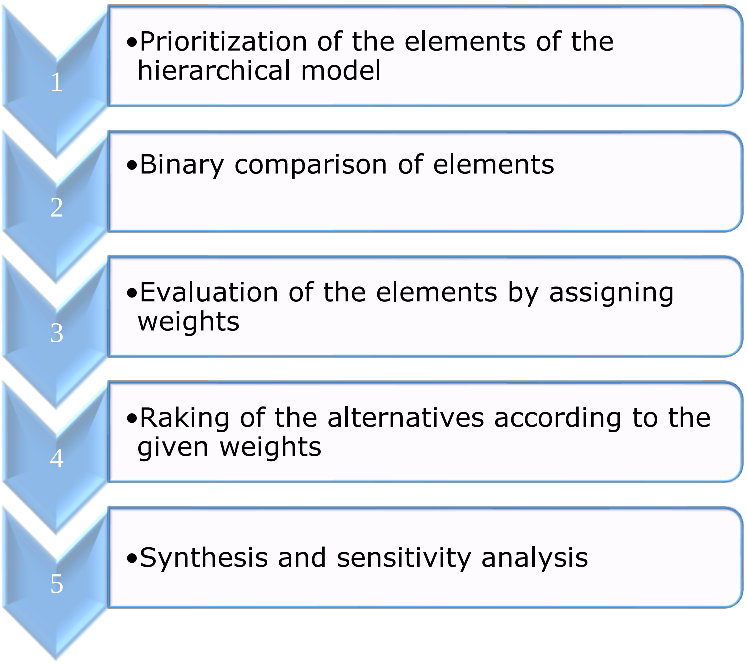

Figure 1. Saaty's AHP methodology.
Source: Own elaboration

For step 1, the following evaluation scale proposed by the author of the method will be used:

Table 1 Saaty Evaluation Scale (Verbal Judgment Rate).

Scale
9 Extremely most preferred
7 Very strongly preferred
5 Strongly preferred
3 Moderately more preferred
1 Equally preferred

Source: (Saaty, 2008)

The following is an algorithm for calculating it (this must be applied for all criteria:

- For each row of the pairwise comparison matrix, determine a weighted sum based on the sum of the product of each cell by the priority of each corresponding alternative or criterion.
- For each line, divide its weighted sum by the priority of its corresponding alternative or criterion.
- Determine the mean ƛmax of the result of the previous step.
- Calculate the consistency index (CI) for each alternative or criterion.

$$CI = \frac{\lambda_{max} - m}{m-1} \quad (2)$$

Where m is the number of alternatives

- Determine the Random Index (AI) of table 2
- Determine the consistency quotient index (the ratio of the consistency index to the random index)

Table 2 Random index for the calculation of the consistency coefficient

Number of alternatives for decision n	Random index
3	0.58
4	0.9
5	1,12
6	1.24
7	1.32
8	1.41
10	1,49

Source: (Saaty, 2008)

RESULTS AND DISCUSSION

Population: The number of establishments that repair electronic products was identified, a total of 187.

Sample: using the formula (1), where:

n: sample size:

N: population size: 187

p: the possibility of occurrence of an event: 0.5

q: the possibility of non-occurrence of an event: 0.5

E: error, for this study an error of 10%=0.1 is considered.

Z: level of confidence, which for 95% is= 1.96

A sample of 64 surveys to be applied is obtained.

Analysis of processed survey results:

1- What type of electronic equipment have you discarded during the year 2021?

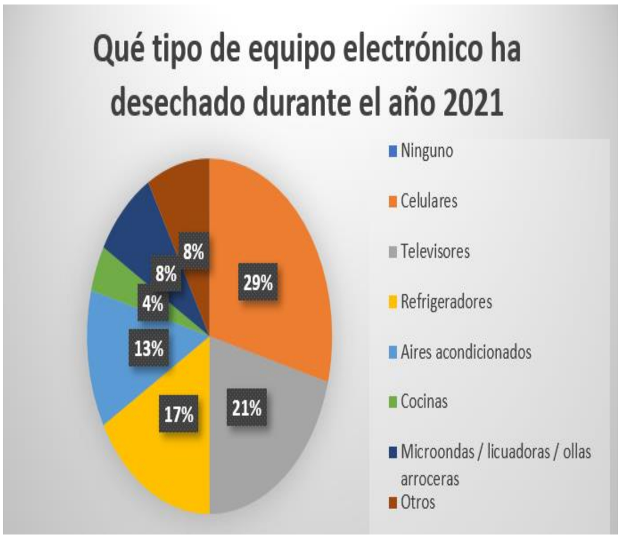

Figure 2. Discarded electronic equipment.
Source: Own elaboration

It can be seen that most of the equipment that is discarded are cell phones, televisions, refrigerators, and air conditioners. In the case of cell phones and televisions, they are the most representative and their recycling is more complex because they are small parts and pieces.

2- On average, how many kg of e-waste do you estimate you produce per month?

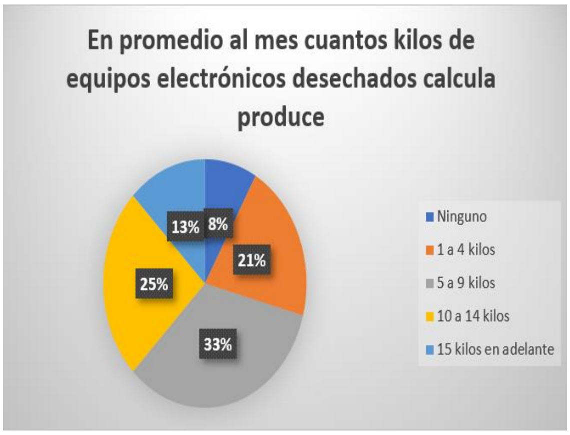

Figure 3. Average waste of discarded electronic equipment. Source: Own elaboration

Most respondents believe that they produce between 1 and 14 kg of electronic waste per month, which is a considerable figure, indicating the need to organize this process and that it is a volume that can be used through recycling.

3- Where do you place the electronic waste you produce?

Figure 4. Destination of electronic waste produced. Source: Own elaboration

Most respondents, 63%, place e-waste in the regular trash, which can lead to inadequate treatment and end up polluting the environment.

4- Do you know of any local regulations governing the management of electronic waste?

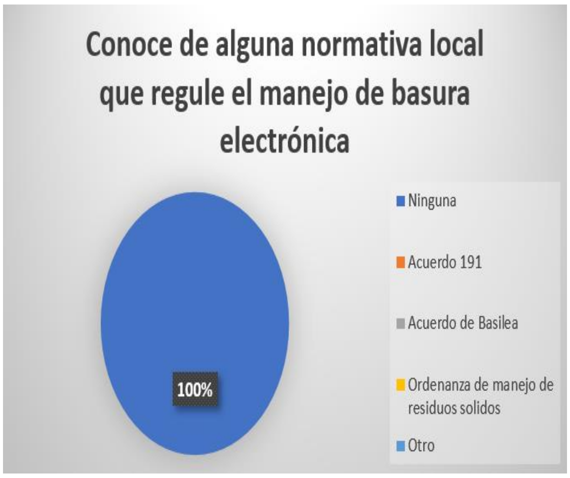

Figure 5. Regulations governing electronic waste. Source: Own elaboration

None of the respondents is informed about the regulations governing the management of electronic waste.

5- Have you been instructed by any entity on e-waste management?

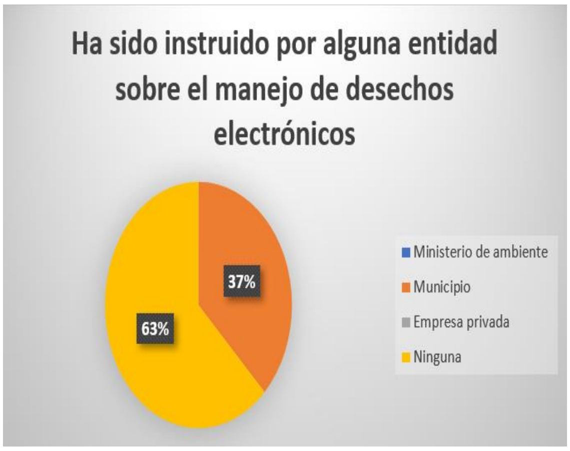

Figure 6. E-waste management instruction by entity. Source: Own elaboration

Most of the respondents were not instructed on waste management, although only 33% acknowledged having received any instruction from the municipality.

6- Do you think it is necessary to create an ordinance to improve the recycling of the electronic waste in Babahoyo?

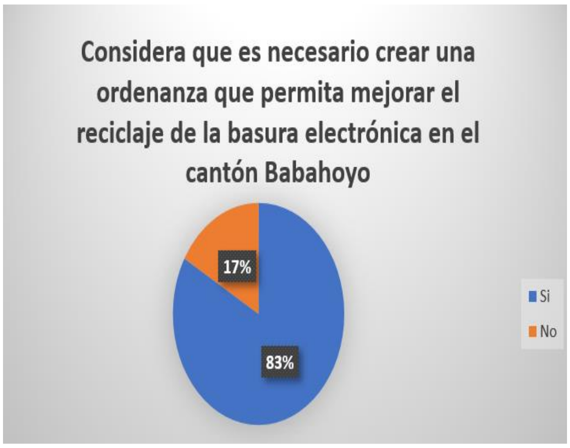

Figure 7. Need for the creation of an ordinance.
Source: Own elaboration

83% of those surveyed consider it necessary to create an ordinance to improve the electronic waste recycling process in Babahoyo.

Summary of diagnosed factors:

1. Considerable volume of electronic waste generated by small electronic equipment repair businesses with no training in this regard.

2. The need to adequately organize the process of waste collection separately from regular garbage.

3. Lack of an ordinance by the Municipality of Babahoyo or at the national level, for proper management and recycling of electronic waste.

It is useful to know the hierarchy of the diagnosed factors to know which ones need to be influenced first, for this purpose the AHP method of Saaty was applied.

The resulting table with the weights after performing the binary comparison matrix of the AHP Saaty is presented below (see tables 4, 5, and 6).

Table 3 Matrix A for pairwise comparison of the criteria

Criteria	CE	PD	NFEA
1. Significant amount of e-waste generated by small electronic equipment repair businesses with no training on the subject.	1.00	0.2	0.3
2. Need to adequately organize the waste collection process separately from regular garbage.	0.40	1.00	2.00
3. Lack of an ordinance by the Municipality of Babahoyo or at the national level for proper management and recycling of electronic waste.	0.30	3.00	1.00
Sum	1.70	4.20	3.30

Source: Own elaboration

Table 4 Normalized Matrix

Criteria	CE	PD	NFEA	**WEIGHT**
1. Significant amount of e-waste generated by small electronic equipment repair businesses with no training on the subject.	0,59	0,05	0,09	0,12
2. Need to adequately organize the waste collection process separately from regular garbage.	0,24	0,24	0,61	0,18
3. Lack of an ordinance by the Municipality of Babahoyo or at the national level for proper management and recycling of electronic waste.	0,18	0,71	0,30	0,20

Source: Own elaboration

Table 5 Analysis of the consistency of the exercise

Criteria	**A x Weight**	**Approx. eigenvalues**	**Own value** =3,0554324
1	0.22	1.789838823	**IC=**0,03
2	0.63	3.481151215	**RC=0.05<0.10**
3	0.78	3.895307167	**Consistent**

Source: Own elaboration

To determine the key alternatives to enhance solutions and eliminate existing system failures, the following hierarchy should be followed:

3 >2>1>, according to Saaty's AHP modeling.

The Saaty AHP modeling defines the highest hierarchical level factor as:

3. Inexistence of an ordinance by the Municipality of the city of Babahoyo or at the national level, for proper management and recycling of e-waste.

2. The need to adequately organize the waste collection process separately from regular garbage.

1. Considerable volume of electronic waste generated by small electronic equipment repair businesses with no training in this regard.

As a result of the survey and the multi-criteria decision method applied, it can be seen that it is necessary to create an ordinance by the Municipality of Babahoyo or at the national level, for proper management and recycling of electronic waste, first, then, the fact that a good part of the waste is of small size, shows the need to properly organize the process through the separate collection of waste. The volume of electronic waste is considerable and therefore constitutes a potential to be exploited for recycling and reuse. However, the fact that most people place electronic waste in the regular garbage and that there is no instruction on the correct way to recycle it, makes it a risk for the environment. While it is true that, in the case of the creation of the same, this is a challenge as a new habit of electronic recycling, establishing a penalty for improper use, is also positive to mitigate the environmental impacts generated due to this type of pollution, thus motivating citizens to have more awareness of the environment and enforce their duties and rights.

CONCLUSIONS

Once the research was carried out, the following conclusions were reached:

E-waste is treated as common garbage, without taking into account a large number of toxic components it contains and the serious repercussions it has on the environment.

To convert e-waste into secondary raw materials, a commitment must be made by all the actors involved in the recycling chain, especially consumers, who must be aware that the devices are treated differently from traditional garbage.

Companies, computer, and cell phone repair shops, and the Ecuadorian society have the problem of electronic waste accumulated in their warehouses, without having options on how to dispose of it.

The fact that a good part of the waste is small in size, shows the need to organize the process adequately.

The volume of waste is considerable and therefore constitutes a potential to be exploited for recycling and reuse. However, the fact that most people place electronic waste in the regular garbage and that there is no instruction on the correct way to recycle it, makes it a risk for the environment.

As a result of the survey and the multi-criteria decision method, it is necessary to create an ordinance by the Municipality of Babahoyo or at the national level, for the correct management and recycling of electronic waste.

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